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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering (Hons) Civil Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis entitled "Influencing Factor of Crushable Sand Soil on Liquefaction is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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INFLUENCING FACTOR OF CRUSHABLE SAND SOIL
ON LIQUEFACTION

THARUSHINI A/P THIAGARAJAN

Thesis submitted in fulfillment of the requirements
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ABSTRAK

Rintangan pencairan pasir sangat dipengaruhi oleh ciri-ciri tanah itu sendiri. Penghancuran atau pecahan butiran pasir berlaku apabila terdapat tekanan yang berlebihan dikenakan pada tanah pasir dan terdapat pengurangan dalam tekanan berkesan pada tanah dan peningkatan tekanan air liang yang menyebabkan pencairan. Dalam kajian ini, tiga lokasi di Pantai Timur Semenanjung Malaysia telah dipilih di mana aktiviti-aktiviti penghancuran tanah seperti pemasangan cerucuk yang biasanya berlaku. Oleh itu, kajian ini dijalankan untuk mengenalpasti faktor utama yang mempengaruhi keretakan tanah untuk berlaku pencairan. Faktor yang mempengaruhi yang telah dikaji dalam kajian ini ialah ketumpatan nisbi dan kesegian. Sampel tanah pasir dari kawasan yang berbeza telah dikumpulkan. Sampel tanah telah dihancurkan dengan menggunakan pemadat automatik untuk 500 dan 1000 pukulan. Selepas proses penghancuran, sampel pasir sebelum dan selepas dihancurkan telah terlibat dalam satu siri ujian di makmal tanah dan geoteknik iaitu analisa ayakan, kaedah piknometer untuk ujian analisa gravity tentu dan uji kaji ketumpatan nisbi untuk menentukan sifat-sifat tanah seperti gravity tentu, ketumpatan nisbi dan pecahan butiran tanah. Mikroskop digital USB telah digunakan untuk menentu butiran tanah untuk mengira indeks kesegian bagi tanah pasir sebelum dan selepas dihancurkan. Penghancuran butiran pasir selepas 500 dan 1000 pukulan dianalisis dengan menggunakan D_{50} Index Pemecahan. Ketumpatan nisbi dan kesegian sampel pasir sebelum dan selepas dihancurkan dikaji mengikut D_{50} Index Pemecahan untuk mengetahui hubungan antara faktor mempengaruhi penghancuran tanah dan potensi pencairan. Berdasarkan keputusan yang diperolehi, ia adalah jelas ketara bahawa kesegian tanah pasir yang dihancur amat mempengaruhi pencairan untuk berlaku.

ABSTRACT

Liquefaction resistance of sand is highly influenced by the characteristics of soil itself. Sand particle crushing or breakage occur when there is excessive stress exert on the sand soil and lead to reduction in effective stress of soil and increase in pore water pressure that result in liquefaction. In this research, the three locations in East Coast Peninsular Malaysia were chosen where the activities of crushing such as pile installation commonly occurs. When the liquefaction potential of the sand soil being affected, this will lead to the failure of construction design which was designed based on existing sand properties by neglecting the conditions of the sand after being crushed Hence, this research was conducted to identify the factor that highly influence the soil's susceptibility to liquefaction. The influencing factors that have been studied in this research are relative density and angularity. The sand soil samples from different area were collected. The samples were crushed by using automatic compactor for 500 and 1000 blows. After the crushing process, the sand samples before and after crushed were subjected to a series of test in the soil and geotechnics laboratory which are sieve analysis test, pycnometer method for specific gravity test and relative density test in order to determine the properties of soil such as, specific gravity, relative density and particle size distribution. The USB digital microscope was used to capture the soil particles in order to calculate the angularity index of the sand soil before and after crushed. The crushability of sand particle after 500 and 1000 blows was analyzed by using D_{50} Breakage Index. The relative density and angularity of sand samples before and after crushed were studied according to the D_{50} Breakage Index in order to find out the relationship between influencing factor of crushable soil and liquefaction potential. Based on the result obtained, it is clearly significant that angularity of crushable sand is highly influencing liquefaction.

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LIST OF SYMBOLS

%	Percent
km	Kilometre
mm	Millimetre
μm	Micrometre
kg	Kilogram
g	Gram
kJ/m^3	Kilojoule per cubic metre
°C	Degree Celsius
ρ	Density
ρ_{dmin}	Minimum dry density
ρ_{dmax}	Maximum dry density
e	Void ratio
e_{min}	Minimum void ratio
e_{max}	Maximum void ratio
Mb	Body-wave magnitude
M_w	Moment magnitude
NL	Number of Layers
NB	Number of Blows
W	Weight of hammer
D	Distance between hammer & sample
V_m	Volume of mold
M_{cws}	Mass of container and wet sand soil sample
M_{cds}	Mass of container and oven-dried sand soil sample
M_c	Mass of container
W_1	Weight of bottle and stopper
W_2	Weight of bottle, stopper and dry soil
W_3	Weight of bottle, stopper, soil and water
W_4	Weight of bottle, stopper and water
M_{S1}	Mass of tested-dry soil 1
M_{S2}	Mass of tested-dry soil 2
V_c	Calibrated Volume of the mold
V	Volume of tested-dry soil
Dr	Relative Density
$R_{p\theta}$	The radius of the particle at a directional angle θ

$R_{EE\theta}$	The radius of an equivalent ellipse at a directional angle θ
B_g	Breakage Index
SP	Poorly Graded Sand
Cu	Uniformity coefficient
Cc	Coeffient of curvature
D_{10}	10% pass particle size in diameter
D_{30}	30% pass particle size in diameter
D_{50}	50% pass particle size in diameter
D_{60}	60% pass particle size in diameter
R^2	Coefficient of Determination
HL	Highly Liquefiable
ML	Moderately Liquefiable
LL	Low Liquefiable
NL	Non Liquefiable

LIST OF ABBREVIATIONS

Mb	Body-wave magnitude
M_w	Moment magnitude
USB	Universal Serial Bus
FS	Factor of Safety
LPI	Liquefaction Potential Index
ASTM	American Society for Testing and Materials
AI	Angularity Index
USCS	Unified Soil Classification System

CHAPTER 1

INTRODUCTION

1.1 Introduction and Background

Liquefaction is the phenomena that have been widely observed which occurs in saturated granular loose sands during numerous traumatic earthquake. Several historical earthquakes like in 2011 Christchurch earthquake in New Zealand, in 2015 Gorkha earthquake in Nepal, in 2016 Kumamoto earthquake in Japan, in 2017 Surigao Del Norte earthquake in Philippine have delineated the disastrous effect of soil liquefaction on buildings and lifelines. (Gautam, Magistris, & Fabbrocino, 2017; Goda, 2016; Serrano, 2017) According to previous research, more than 130 earthquake phenomena had occured in Sabah with magnitude ranging from 1.9 to 5.9 Mb. Recently in 2015, Sabah has experienced a destructive earthquakes at Kinabalu with magnitude of 5.9 Mb at 10km depth. (Lim, 2015; Chan, 2017). Moreover, Ranau and Kunak have been experienced a mild earthquake with magnitude 4.2 Mb and 3.2 Mb lately on March 2017 (Inus, 2017). Therefore, it is wise to be aware of the liquefaction potential in Peninsular Malaysia as Sabah is proven to be vulnerable to liquefaction.

Crushable sand which caused by high stress exerted on the sand particles are considered fragile and are frequently encountered in places where liquefaction phenomena occurred (Liu, 2015). Crushed sand soils are normally resulted from human activities such as pile installation, construction of high earth or rock fill dams, impact of projectiles, laying foundations of the offshore gravity structures and so on (Lobo-Guerrero and Vallejo, 2005; Wood, 2006; Bartake and Singh, 2007). The characteristic of the crushable sand soils will change the original engineering properties which a structure was initially designed accordingly. This influence the possibility of soil liquefaction to be occurred under consideration of the effect from the new soil properties after being crushed.

From the past history of liquefaction, it has illustrated that there are few factors that can be considered with the liquefaction susceptibility of granular soils. Past researchers have indicated that liquefaction susceptibility of sand soil decreases when the relative density increases. There is a limit value where the sand particles become susceptible to liquefaction in term of grain size of sand soils (Hakam, 2016). In respect of angularity of sand soils, the more angular the sand is the more susceptible the sand is to liquefaction compared to rounded sand at high confining pressure even at the relative density approaching 100% for moderate earthquakes (Chern, Tumi, & Student, 1986). Only few studies in the literature have specifically evaluated any of the factors such as angularity, particle size distribution or relative density alone that influence the occurrence of liquefaction. However in an attempt to relate the relative density and angularity, this research have been carried out to analyse the most critical influencing factors of sand soil on liquefaction.

1.2 Problem Statement

Sand crushing will commonly occur in construction site. For example, sand particle breakage happen during pile driving, compaction for cut and fill, compaction during road and earthwork construction. The sand crushing or breakage of sand soil particle due to exposure of high pressure on the sand affects the properties of the existing sand soil. This can lead to occurrence of liquefaction after the crushing of sand particles took place when the crushed sand does not maintain the same properties which they had during design stage. There were influencing factor of crushable sand particle that lead to the possibility of soil susceptible to liquefaction which are relative density and angularity. Hence, a research was conducted to identify the influencing factor of crushable sand soil that lead to crushing and analyse the most critical influencing factor of crushable sand soil on liquefaction.

1.3 Research Question

This study aimed to address the following research questions.

i. Does the denser soil liquefy easily when the soil is crushable?

ii. Does the more angular soil liquefy easily when the soil is crushable?

iii. Does density of sand is the most influencing factor for liquefaction than the angularity of the sand?

1.4 Research Objectives

The main purpose of this research is to study the influencing factor of crushable sand soil from East Coast Peninsular Malaysia on liquefaction susceptibility. Three specific objectives have been listed below in order to achieve the aim of this research.

i. To determine the relationship between soil relative density and crushability.

ii. To determine the relationship between soil angularity and crushability.

iii. To identify the most influencing factor of crushable sand soil on liquefaction.

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